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A CANADIAN SURVEY OF AUTOMOBILE TIRE PRESSURES, TIRE FAILURES A--ETC(U)
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A Canadian survey of automobile tire pressures, tire failures, and tire maintenance practices.

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A CANADIAN SURVEY OF AUTOMOBILE TIRE PRESSURES, TIRE FAILURES AND TIRE MAINTENANCE PRACTICES

(10)

Dennis A. Attwood
~~and~~
Raymond D. Williams

Road Safety Unit
Road and Motor Vehicle Traffic
Safety Branch
Transport Canada

attached to the
Defence and Civil Institute of
Environmental Medicine
Downsview, Ontario

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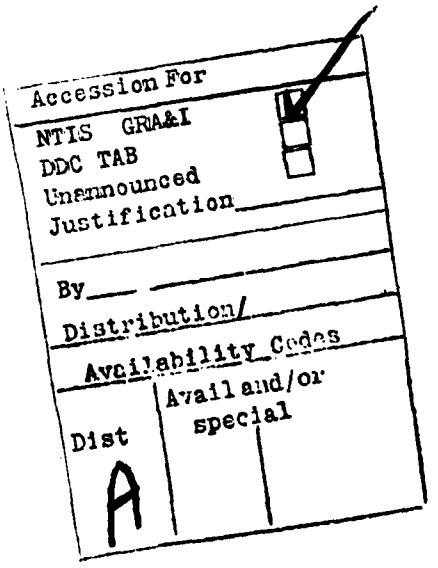

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SUMMARY

Previous limited tire pressure surveys have suggested that the tire pressures on Canadian vehicles are critically low and could be resulting in an abnormally high number of tire failures. Many tires examined by Transport Canada as a result of complaints of alleged safety defects were found to have failed as a result of underinflation.

In December, 1978, Transport Canada initiated a national tire maintenance survey that was designed to:

- obtain a nationally representative sample of tire pressures to determine whether out-of-limits pressures were a serious problem;
- record driver maintenance habits and characteristics and attempt to relate these to tire pressures (the strength of these relationships could suggest potential countermeasures if a tire pressure problem existed);and
- obtain cursory information on the number and types of tire failures that have occured over the last three years.

The survey data were obtained from interviews with 745 householders selected at random from across the country. The data obtained from each interview included the sex and age of each driver, the physical properties of the tires on his or her vehicle, the reported vehicle and tire maintenance habits of each driver, and the number and types of tire failures that he or she may have experienced in the past.

Results indicated that at least 70 percent of the tires in the survey were underinflated, and as many as 37 percent were underinflated by 4.0 pounds per square inch (psi) or more. Moreover, almost 90 percent of the vehicles had at least one tire that was underinflated, and almost 60 percent of the vehicles had at least one tire that was underinflated by 4.0 psi or more.

The data clearly shows that all groups of drivers and all classes of vehicles have serious underinflation problems. Some groupings can be linked with slightly lower tire pressures:

1) Young (16-24) females have the lowest tire pressures (young males 16 - 24 are the lowest male group).

2) Those who checked their air pressure less frequently have slightly lower tire pressures.

3) Those who checked their tire pressures themselves have slightly higher tire pressures then those who have their tires checked by somebody else.

4) Tires on medium and full-sized cars, particularly non-radials with a 14 inch diameter, tended to be more underinflated.

5) Tires mounted on the rear of vehicles were more underinflated than those mounted on the front.

Results also indicated that over 27 percent of the respondents reported having replaced at least one tire in the last three years for reason other than normal wear and tear. Excessive wear, bulges or bumps, blow outs and tread separation were given as the most frequent reason for replacing the tires.

86% of drivers claimed that the tires on their car have been checked at least once in the previous six months, either personally (59%) or by someone else (41%). 75% of respondents, 83% of males, 65% of females, were willing to estimate the proper tire pressures for their car. These two statistics seem to indicate that people are interested and concerned with maintaining proper tire pressure.

The survey shows that all people, driving all types of cars, in all parts of Canada, using either radial tires or non-radials are not maintaining sufficient pressure in their tires. In spite of apparent concern for the problem more than half of the car owners have at least one tire seriously underinflated. Possible reasons for this are:

1) Changes in outside temperature - a drop of $10^{\circ}C$ can cause tire pressure to drop about 2 psi.

2) Infrequent checking of pressure - less than 27% of respondents checked their tires monthly with a gauge.

3) Inaccurate tire gauges or pumps.

4) Tires are checked when warm rather than cold -tire manufacturers specify pressures for cold tires.

5) Tires mounted on the rear of vehicles typically require more air pressure than those mounted on the front.

SOMMAIRE

Certain sondages menés au Canada ont démontré que la pression des pneus des véhicules est en général dangereusement basse et qu'elle pourrait occasionner un nombre anormalement élevé de défaillances des pneus. L'examen par Transports Canada d'un grand nombre de pneus au sujet desquels des plaintes concernant de prétendus défauts relatifs à la sécurité avaient été formulées, a démontré que la défaillance de ces pneus avait été causée par le sous-gonflage.

En décembre 1978, Transports Canada a entrepris une enquête nationale sur l'entretien des pneus, qui visait à:

- obtenir un échantillonnage représentatif de la pression des pneus, pour l'ensemble du pays, afin de déterminer si le mauvais gonflage de ces derniers constituait réellement un problème grave;
- relever les habitudes d'entretien des conducteurs et les caractéristiques de chacun au volant, et essayer de les relier à la faible pression des pneus (si elles engendrent le problème de sous-gonflage, il faudrait peut-être prendre certaines mesures appropriées pour remédier à la situation);
- obtenir des données préliminaires quant au nombre et aux genres de défaillances de pneus survenus au cours des trois dernières années.

Les données de cette enquête ont été recueillies au moyen d'entrevues menées parmi 745 chefs de famille choisis au hasard d'un bout à l'autre du pays. Ces renseignements comprenaient le sexe et l'âge des conducteurs, les caractéristiques techniques des pneus dont est muni leur véhicule, leurs habitudes déclarées d'entretien de celui-ci et des

pneus, et le nombre ainsi que le genre de défaillances de pneus auxquels ils ont eu à faire face.

Les résultats ont montré qu'au moins 70% des pneus concernés par l'enquête étaient insuffisamment gonflés, et que pas moins de 37% indiquaient un écart de 4 livres ou plus par pouce carré par rapport à la pression requise. De plus, près de 60% des véhicules avaient au moins un de leurs pneus auquel il manquait 4 livres de pression ou plus par pouce carré.

Les données démontrent clairement que tous les groupes de conducteurs et toutes les catégories de véhicules et de pneus donnent lieu à de graves problèmes de sous-gonflage. Les pressions les plus faibles ont été relevées lorsqu'il s'agit:

1) de femmes âgées de 16 et 24 ans, pour lesquelles on a enregistré les plus faibles pressions (chez les hommes, ce sont les conducteurs âgés de 16 à 24 ans qui gonflent le moins leurs pneus);

2) de conducteurs et conductrices qui vérifient le moins souvent la pression de leurs pneus;

3) de conducteurs et conductrices qui utilisent les distributeurs d'air comprimé des stations-services de préférence à l'indicateur de pression portatif;

4) de conducteurs et conductrices de voitures de taille moyenne et de grosses voitures, et plus particulièrement de voitures munies de pneus non radiaux de 14 pouces de diamètre;

5) de pneus arrière.

L'enquête a également révélé que plus de 27% des répondants ont déclaré avoir remplacé au moins un pneu au cours des trois dernières années, pour des raisons autres que l'usure normale. Parmi ces raisons, on trouve principalement la détérioration anormale du pneu, l'apparition de bosses ou de renflements, l'éclatement et la séparation de la bande de roulement.

Au total, 86% des conducteurs affirment que les pneus de leur voiture ont été vérifiés au moins une fois au cours des six derniers mois; 59% ont procédé eux-même à l'inspection tandis que 41% l'ont fait faire. Sur l'ensemble des répondants, 75% (83% des hommes et 65% des femmes) ont pu indiquer correctement la pression appropriée des pneus de leur voiture. Ces résultats semblent démontrer que les conducteurs et conductrices sont conscients de l'importance d'assurer à leurs pneus la pression appropriée.

L'enquête indique que la plupart des conducteurs et conductrices, peu importe le genre de voiture, leur lieu de domicile au Canada ou le fait qu'ils utilisent ou non des pneus radiaux, ne maintiennent pas leurs pneus à la pression requise. Malgré la prise de conscience générale que semblent indiquer les résultats, plus de la moitié des propriétaires de voiture ont au moins un pneu de leur véhicule qui est dangereusement sous-gonflé. Cette situation peut s'expliquer par les raisons suivantes:

1) changements dans la température ambiante (une baisse de 10°C peut entraîner une diminution de la pression des pneus de l'ordre de 2 livres par pouce carré);

2) vérification insuffisante de la pression (moins de 27% des répondants affirment vérifier leurs pneus tous les mois);

3) indicateurs de pression ou distributeurs d'air comprimé défectueux;

4) vérification des pneus lorsqu'ils sont chauds (la pression recommandée par les fabricants est pour les pneus à l'état stationnaire avant le roulement).

5) les pneus arrière nécessitent une plus haute pression que les pneus avant.

INTRODUCTION

According to the tire manufacturing industry the improper inflation of tires can adversely effect tread life (1) and gas mileage (2). Moreover, underinflation can lead to the sudden and complete failure of the tire (3) which, at highway speeds, can have catastrophic results.

While we can all visualize how far we would travel on a flat tire before it is destroyed, its more difficult for us to imagine how long it would take for a tire to fail with just a little bit of air in it. When a tire is underinflated, its side walls flex. This flexing builds up heat which causes irreversible damage to the tire material. Clearly, the more underinflated a tire is, or the faster it rotates or the more load it is made to bear, the more it flexes and the faster it fails. Unfortunately, the empirical data relating inflation pressure, vehicle speed and tire load to the probability of failure are not available outside of the tire industry (4). Instead, tire manufacturers tell us that a tire is dangerously underinflated when it is four pounds per square inch (psi) or more under the recommended pressure.

It appears that the tires on the majority of cars in North America are underinflated. Viergutz et al (5), surveyed the pressures of about 10,000 radial tires in the Chicago area. Their data indicated that, in the summer 50 to 70 percent of the tires examined were underinflated and in the winter 60 to 80 percent. Moreover, about a third of all tires were underinflated by four psi or more.

In Canada, the situation does not appear to be any better. Two small surveys have been recently reported by provincial motor leagues. In a Manitoba survey (6), 15% of 510 cars inspected "had faults with tire pressure and spare", and in an Ontario survey (7), 33.6% of 372 cars had low air pressure or defective tires.

While each of the above reports suggest that there is an alarmingly high incidence of underinflated tires on the road, surprisingly little effort has been expended to find out why. One survey, conducted by the Canadian Automobile Association (8), attempted to relate the state of repair of vehicles with the reported use of self-service gas stations. Their data suggested that 43% more tire pressure problems were found on vehicles whose owners used self-serve stations most of the time.

The survey described herein was conducted for three reasons. First, to gather a representative sample of automobile tire pressures from across Canada. These data can be used to determine whether out-of-limits pressures are a serious problem requiring a countermeasures program. Second, the survey attempted to relate incidents of out-of-limits tire pressures, with a set of driver characteristics that were thought to be associated with proper vehicle maintenance. The strength of these relationships could suggest the most cost-effective areas for countermeasure development. Finally, the survey sought to obtain cursory information on the number and types of tire failures that occur.

METHOD

General procedure

Interviews were conducted with approximately 750 householders chosen at random from across the country. Since the costs of a survey escalate as the sampled population becomes more scattered, it was decided to limit the sample to urban centres with populations of 30,000 or more. This population represents about 62% of Canadian households.

The population was stratified into groups by region and population density. The number of households selected for each group was proportional to the percentage of the total population contained in the cell.

A list of candidate cities for the survey was prepared for each population density stratum (cell) within each region. The cities to be sampled were then selected randomly. The only constraint on random selection was that the major centers of Montreal, Toronto and Vancouver had to be represented.

The number of household interviews conducted within each city was proportional to the relative number of households in each. Table 1 lists the number of interviews conducted in each of the 20 cities that were finally selected.

Three interviews were normally conducted for each starting point chosen within a city. Starting points were selected randomly from census tracts prepared for each city. If the interview could not be completed at a household that was originally selected, the interviewer called back twice before substituting another one

The interviewer was instructed to interview the driver of the vehicle that was driven most often within a household. If this driver was unavailable, even with call-backs, the driver of another vehicle (if available) in the household was interviewed.

Household interview

The household interview was functionally divided into two separate parts. During one part of the interview, the tires of each respondent's car were physically examined to determine their condition. During the second part, each respondent was asked about his/her driving and vehicle maintenance habits, and about previous tire failures that had been encountered. Questions were read directly from prepared questionnaires (a French language version was used in Quebec), and the data were recorded on the same form.

Tire examination: Each interviewer was provided with a bourdon-tube type pressure gauge which was read to the nearest pound per square inch (psi), a disposable flashlight, and a small plastic ruler.

Interviewers were instructed to record the following information from the tires;

- tire make, size, and type (ie. radial or not),
- whether tire was 'bald' (ie. was worn smooth for three or more inches across the tread surface),
- whether tire had summer or winter tread, and
- tire pressure (at least two readings per tire and a third if the first two varied by more than one psi).

Inflation pressures were obtained only if the car had been stationary for an hour or more. If it had not been sitting for at least an hour, the interviewer called back at a later time to complete the interview.

Personal interview: After recording the make, model, and year of the respondent's automobile, the interviewer was instructed to ask questions which examined the following topics.

Driving and maintenance habits;

- proportion of driving time spent on roads with speed limits above and below 70 kph.
- proportion of occasions that respondent used self-serve stations,
- knowledge of recommended tire pressures,
- number of times tire pressures had been checked in the past six months and, if they hadn't been checked, why,
- who routinely checked the tire pressures,

- what problems, if any, had been encountered when tires were checked, and
- when the vehicle was last serviced.

Tire failures;

- number of tires replaced for reasons other than normal wear and tear over the past three years,
- make, model and size of the last tire that had to be replaced, and
- the reason why it had to be replaced.

RESULTS

Survey breakdown by major descriptive statistics

The number of respondents from each age range and sex that were actually interviewed in each region are listed in Table 2. The ratio of males to females, and the frequency of respondents in each age range appear to resemble the characteristics of the driving population. The reader will note that 745 respondents were interviewed rather than the original target of 750.

Table 3 lists the number of tires surveyed by major manufacturer and type (ie. radial/non-radial). Of the 2980 tires examined, 50.4% were non-radials, 47.4% were radials and 2.2% couldn't be identified.

For thirty-six percent of the tires examined, the manufacturer's name could either not be read from the tire, or the tire was made by a manufacturer other than the eight originally coded. The major manufacturers in the 'other' category were hand tabulated and are included in Table 3. Since the manufacturers in the 'other' category were not machine coded, further analyses of these data were not feasible.

Table 4 shows that about 63% of the tires examined had summer treads, 35% were winter tires and the remainder could not be identified. The table also indicates that only about 4% of the tires examined were 'bald', that is, had no tread for three or more inches across the tread surface.

Characteristics of the major distributions

Differential tire pressures are used exclusively in all descriptive statistics, and most of the analyses to follow. The differential pressure ΔP is defined for each tire as follows;

$$\Delta P = \frac{\text{Sum of two pressure measurements}}{2} + \text{gauge correction} - \text{recommended pressure}$$

The 'gauge correction' is the reading error of each of the 104 gauges sent into the field. These errors ranged from plus to minus 2 psi on a 25 psi standard.

The 'recommended pressure', inserted for each individual vehicle, was obtained from the industry's tire pressure handbook (9). When a number of options existed for a particular type of car, eg. a 1973 Chevrolet Impala, sedan, the lowest recommended pressure was used. Consequently, the differential pressures used in the analyses were likely greater, on average, than those actually occurring in the field.

Figure 1 presents a frequency distribution and histogram of the differential pressures of each individual tire that had measured pressures greater than 5 psi. Clearly, the distribution demonstrates that, on the average, the majority of the tires on Canadian vehicles are underinflated. Table 5 indicates just how serious the underinflation problem is. The tabled data are estimates of the percentage of tires at or below a given differential pressure. The data indicate, for example that 37.3% of all tires were underinflated by 4.0 psi or more. The Table also lists in brackets ( ) a confidence interval on the percentage estimate. Referring again to Column 2 of Table 5 we can say that there is a 95 percent probability that between 35.5 and 39.1 percent of all tires represented by the sample were underinflated by 4.0 psi or more.

Considering only the percentage estimates and using 4.0 psi underinflation as the critical pressure, the highest percentage of critical underinflations was for non-radial tires (46.0%) with 14 - inch inside diameters. The lowest percentage is for radial tires (27.2%) with inside diameters less than 14 inches.

Figure 2 and Table 6 describe the same categories of tires as above, but in terms of minimum differential pressures. The minimum differential pressure ($MIN\ \Delta P$) is defined as the lowest of the four differential pressures on each vehicle. This variable, in many ways, most accurately reflects the probability of a tire failing on a vehicle. Owing to the characteristics of the analysis program, the minimum differential pressure on a vehicle is included for analysis only if all four of the vehicle's tires have a pressure reading of at least 5.0 psi. Similarly, the program includes minimum differential pressures for an individual tire category, eg. radials, only if all four tires on the vehicle fall into that category.

Examining the distribution in Figure 2, it becomes immediately apparent that almost all vehicles have at least one underinflated tire and, further, that 60% of the vehicles have at least one tire that is critically underinflated (-4.0 psi or less). The category of vehicles with the highest percentage (67.9%) of minimum differential pressures at or below -4.0 psi is non-radial tires with 14 inch inside diameters. The category of vehicles with the lowest percentage (51.9%) of minimum differential pressures less than or equal to 4.0 psi underinflation is radial tires with inside diameters less than 14 inches.

Summary of responses to individual survey questions

The following paragraphs examine the responses received from the 745 householders to each of the questions asked during the interview. The questions (Q) and response sets (R) are reproduced in their entirety.

Q2: *About how much of your mileage in this vehicle is done in speed limit zones of under 70 kph?*

R2:
- *None or almost none*
- *About a quarter of it*
- *About half of it*
- *About three quarters of it.*
- *All or almost all of it.*

Almost all respondents (88%) reported spending at least half of their time, and as many as 64% most of their time, on roadways with speed limits under 70 kph. Only about 3% of the respondents reported spending almost no time on low-speed roadways.

Q3: *When you fill this car with fuel, about how often, if ever, do you go to a self serve station?*

R3:
- *Never or almost never,*
- *About a quarter of the time.*
- *About half the time.*
- *About three-quarters of the time.*
- *Always/almost all the time.*

The data show that more respondents use self-serve stations than full service stations. Sixty percent of the respondents reported using self-serves half the time or more. Only 33% report that they never use self-serve stations and 41% report that they always use them.

Recalling the survey conducted by the Canadian Automobile Association (8) on vehicle problems associated with the use of self-serve stations, one question that is examined in the next section is whether the use of self-serve stations leads to higher underinflations.

Q4a: *While tire pressures are recommended in your owner's manual for this vehicle? First of all, for the front tires?*

R4a: _____ *psi*

Q4b: *And for the rear tires?*

R4b: _____ *psi*

Seventy-five percent of the respondents were willing to estimate what the recommended tire pressures were for their vehicles. Their estimates were, on average, 1.4 psi higher for the front tires than the pressures recommended by the manufacturers. However, the mean of the estimates for the rear tire pressures was nearly perfect.

Q5: *In the past 6 months, about how many times, if at all, have the tire pressures on this car been checked with a pressure gauge?*

R5:
- *None*
- *Once*
- *Twice*
- *3 or 4 times*
- *5 or 6 times*
- *More than 6 times*
- *Don't know*

Eighty-six percent of the respondents reported having their tires checked at least once within the previous six months. Forty-four percent reported having their tires checked three times or more.

Q6: (Of those who had their tires checked)...*During this time, have you yourself checked the tire pressures with a gauge?*

R6:
- *Yes*
- *No*

Of the 638 respondents who reported having their tire pressures checked at least once in the last six months, 59 percent of them reported that they checked them personally.

Q7: (Of those who checked their pressures personally)..... *In the past six months when you yourself checked the tire pressures, did you usually.....*

R7:
- *Use your own gauge?*
- *Use the air pump at the Service station?*
- *Borrow a gauge from a Friend?*
- *Borrow a gauge from service station attendant?*
- *or, just what?*

Of the 379 respondents who checked their pressures personally, almost 60 percent used their own gauge. The next most popular method of checking tire pressures was with the stations' air-pump/pressure-gauge systems (27%).

Q8: (Of those who checked their tire pressures personally).. .....*On those occasions, did you have any problems checking the tire pressures on this vehicle, or not?*

R8:
- *Yes*
- *No*
- *Don't know*

Only 12 of the 379 respondents claimed to have had a problem checking their pressures. The problems were mainly (Q9) with the tire valve.

Q10: (Of those 259 respondents who claimed to have their tire pressures checked by somebody else)...*Who, if anyone else, checks the tire pressures on the vehicle with a pressure gauge?*

R10:
- *No one else*
- *Station attendent*
- *Male(s) in family*
- *Female(s) in family*
- *Other male(s)*
- *Other female(s)*
- *Other (specify)*

The data suggest that the station attendent still plays a major role in the service of tires. Two hundred respondents reported having their tires checked by an attendent. This number represents 27% of the total number of survey respondents.

Q11: (of those who did not have their tires checked in the past six months)...*What would you say is the main reason why the tire pressures on this vehicle are not checked with a gauge?*

R11:
- *Don't know how to.*
- *Make visual check (just look at them).*
- *Can't be bothered.*
- *Don't have a gauge*
- *Other*

Of the 106 respondents who reported not having their tires checked, 25% of them said they couldn't be bothered, and 39% said they make a visual check. Only a fraction said they didn't know how to check their tires or that they didn't have a gauge.

Q12: *When was the last time this vehicle was serviced; that is, given an oil change and greased?*

R12:
- *Within the past three months.*
- *Over 3 to 6 months ago.*
- *Over 6 to 9 months ago.*
- *Over 9 to 12 months ago.*
- *More than 12 months ago.*
- *Don't remember*
- *Never*

This question was asked to determine whether general vehicle maintenance habits (or lack of them would be related to differential tire pressures.

Ninety-five percent of the respondents reported having their cars serviced within the past six months and 85% within the last three months.

Q13: *Thinking of any vehicle you've owned during the past three years, how many tires, if any, have you had to replace for reasons other than normal wear and tear?*	R13: - *None* - *One* - *Two* - *Three* - *Four or more*

Two hundred and four, or over 27% of the respondents reported replacing at least one tire for reasons other than normal wear and tear over the past three years.

Q14a;Q14b: *What brand was the last tire you had to replace? (for reasons other than normal wear and tear).*	R14a;R14b: - *Atlas* - *Canadian Tire* - *Dayton* - *Firestone* - *General* - *BF Goodrich* - *Goodyear* - *Uniroyal* - *Other*
Q15: *Was this a radial tire, or some other kind of tire?*	R15: - *Radial* - *Other kind*
Q16: *What size was the tire you had to replace? Was it.....*	R16: - *13 inch or less?* - *14 inch* - *15 inch or more?*

The last tires that our respondents reported replacing for reasons other than normal wear and tear are listed in Table 7 by make, tire type (radial/non-radial) and two categories of tire size. The reader should keep in mind that the table entries are absolute numbers and do not necessarily reflect either the number of tires of a given type that had been in service or the number or type of miles that each had been exposed to.

Notwithstanding the above, the data suggest that radial tires are overrepresented in the defects.

Q17: *What was the problem with this tire that it had to be replaced?*

R17:
- *Wore out too fast.*
- *Blow out.*
- *Tread separation.*
- *Couldn't get balanced.*
- *Bulge or bump.*
- *Kept losing air.*
- *Other.*

The reason reported most often for having a tire replaced was because it wore out too fast (19%). The categories that are typically related to tire failure, bulges, blow-outs or tread separation, amount, in total to only 39% of the problems reported.

Analyses for potential countermeasures.

As well as describing the on-road tire pressures of Canadian vehicles, the survey was designed to examine the relationship between differential pressure and a number of other variables. This section analyzes response and tire pressure data by the following major categories;

* age, sex, and region of principal driver.
* tire maintenance habits of drivers,
* vehicle maintenance habits of drivers, and
* tire type and tread, and location on the vehicle.

In addition, some combinations of categories are analyzed (eg. females, by age group) whenever the first level of analysis suggests them. The reader should appreciate, however, that the number of ways of combining variables is extremely large, so, only a few of the possible combinations are examined.

Age, sex and region of principal driver: The responses to several interview questions were sub-grouped by sex and major age categories. While no statistical analyses were conducted on these data, the following points summarize the results;

- there appears to be little difference in the use of low-and high-speed roadways by males and females.
- females appear to use self-serve stations less than males. For example, 44% of the female respondents reported using self-serves more than half the time compared to 53% of the males.
- 83% of the males interviewed were willing to estimate their recommended tire pressures compared to 65% of the females. However, the mean pressures estimated by males were not significantly different from those estimated by females.
- there appears to be little difference between the number of times males and females have (or don't have) their tire pressures checked however,
- a higher percentage of males (73%) check their own tires than do females (45%),
- those who typically have their tires checked less frequently are females and males between the ages of 35 and 55 years,
- only about three percent of males and females who check their tires encounter problems,

While there appears to be little, if any, difference in the tire maintenance practices of males and females, mean minimum differential pressures (*MIN ΔP*) do differ by sex. The data show a small (0.8 psi), but significantly lower mean pressure on vehicles driven principally by females. Separating these data into different age groupings, Table 8 suggests that, among females, the 16 to 24 year olds have the worst minimum differential pressures. This group is followed by females 55 years old and older. Among the men, the 16 to 24 year olds also appear to have the lowest tire pressures, while those in the 45-54 age range have the highest.

Table 9 presents the means and variances of *MIN ΔP* by the five regions surveyed. A one-way analysis of variance performed on these data suggests that the mean *MIN ΔPs* were significantly different between regions ($F=3.1$, $p < .025$). Closer examination of the data reveals that the vehicles in British Columbia had much lower differential pressures (higher average tire pressures) than those in any other region. These elevated tire pressures are likely due to the significantly higher mean air temperatures in B.C. (+ 4 degrees C) than in the rest of the country (- 5 degrees C) during the survey. A pressure differential of 9 degrees C could change tire pressures by as much as 2.0 psi, which would account for the difference.

Tire maintenance habits of drivers: The means and variances of *MIN ΔP* from vehicles whose drivers reported having pressures checked in the last six months were compared against those from vehicles whose drivers hadn't had their pressures checked. The analyses suggest that;

- the mean *MIN ΔP* on the vehicles of those drivers who hadn't had their tires checked in six months (-7.0 psi) was significantly less ($t=2.61$, $p < .005$) than the mean *MIN ΔP* on the vehicles of those who had (-5.4 psi), and

- the variance of the *MIN* ΔP for the vehicles whose drivers hadn't had their tires checked in the last six months was significantly greater ($F=1.55$, $p< .01$) than the variance of the vehicles whose drivers had.

The mean and variance of *MIN* ΔP for the vehicles of those drivers who reported checking the pressures of their tires themselves were compared against those for the vehicles whose drivers reported having them checked by somebody else. A 't'-test performed on these data suggests that the mean *MIN* ΔP on those vehicles whose drivers checked their tire pressures personally was about one psi greater than that on those vehicles whose drivers had their pressures checked by somebody else. This difference is statistically significant ($t=2.02$, $p< .025$).

It has been suggested that the tower pump/gauges at service stations are routinely inaccurate. So, the mean and variance of *MIN* ΔP from those vehicles whose drivers used their own gauges were compared with the mean and variance from those vehicles whose drivers used the service stations' pump/gauges. The data show that;

- the *MIN* ΔPs are significantly more variable ($F=1.39$, $p< .05$) among the vehicles whose drivers use service station pump/gauges, though

- the mean *MIN* ΔP is slightly, but not significantly, lower for these vehicles than for the group of vehicles whose drivers use their own gauge.

Vehicle maintenance habits of drivers: One survey conducted by the Canadian Automobile Association (8), suggested that those who routinely use self-service stations might be neglecting to perform routine preventive maintenance on their vehicles. Their suggestion was based, in part, on the significant number of tire pressure problems recorded from those vehicles driven by self-serve users. Consequently, the mean and variance of *MIN* ΔP for the vehicles of those drivers who reported never using self-serve stations was compared with the mean and variance for the vehicles of those drivers who reported always using them. The data do not support the above hypothesis, since there was little difference between the means or variances of *MIN* ΔP on the two groups of vehicles.

Continuing with the general topic of vehicle maintenance, the mean and variance of *MIN* ΔP for those drivers who reported servicing their vehicles within the past six months was compared with the mean and variance for those who reported not servicing their vehicles within the past six months. Again the analyses indicate that there is no reason to believe that vehicle maintenance habits are related to *MIN* ΔP.

Tire type, tread and location on the vehicle: Considering that the survey data were obtained in early December, soon after most drivers had installed snow tires, it was predicted that there would be little difference between the front and rear differential pressures (ΔP). Analyses of the two groups of data, however, by different classifications revealed the following;

- there is no difference in the means ΔP of tires by seasonal tread.
- the mean ΔP of rear tires is about 1.6 psi lower than the mean ΔP on front tires. This difference is highly significant.

- comparing only summer tires on the front with summer tires on the rear, the mean ΔP for the rear tires is still significantly lower than that for the front tires.

Table 10 compares the means and variances of ΔP across the six combinations of tire type and size. A one-way analysis of variance performed on these data indicates that there was a significant difference ($F=10.3$, $p< .005$) across the six mean pressures. Posterior comparisons across means indicate that the mean ΔP of non-radial tires with a 14-inch inside diameter was significantly lower than the mean ΔP of all other categories except radial tires with inside diameters greater than 14 inches.

DISCUSSION AND CONCLUSIONS

The results of this survey confirm the findings of other Canadian surveys, namely that the majority of tires on Canadian vehicles are underinflated and, in many cases, underinflated by a significant amount. Moreover, comparing our data with those reported by Viergutz (5), the pressures of radial tires in the Canadian survey appear to be only marginally higher than the winter pressures of radials in the Chicago survey of 1977. The percentage of radials underinflated by more than 4.0 psi for example, ranged from 29% to 47% in the Chicago survey, depending on tire size, and from 27% to 36% in our study. Even so, the data have several characteristics in common. Both sets, for example, demonstrated a decrease in mean pressure as the size of the tires increased, indicating that tire pressures on the larger cars in both studies were worse than those on smaller cars.

Similar trends were evident for non-radial tires in the Canadian data, though, in absolute terms, the results were much worse than for the radial sample. By far the worst group of tires was the non-radials with a 14-inch inside diameter. The mean minimum differential pressure on vehicles with these tires on all four wheels was almost 2.0 psi less than the vehicles with small radial tires ..... our best group. Fourteen inch non-radial tires were typically found on both cars and station wagons more than two years old (one-third of these tires were found on 1974 to 1976 vehicles). As an aside, 85% of non-radial tires were found on vehicles two or more years old and 76% of all radial tires were found on vehicles less than five years old.

In terms of driver characteristics, the data indicate that drivers in the 16 - 24 age group, particularly females in this group, had lower tire pressures than the older drivers. In order to describe the driving habits of these younger drivers, the percentage of the total male drivers 16 to 24 years old that fell into each category of a survey question (eg. 21% never use self-serves, Table 11), was compared against the percentage of male drivers above 25 years old (eg. 28% never use self-serves, Table 11)that fell into the same category. The same comparisons were made for females. Those categories, or combinations of categories, where the difference in the percentages of younger and older drivers was at least 10% (eg. 28% minus 21%= 7% in Table 11) were then recorded. The following characteristics emerged from the procedure.

Use of self-serve

Both male and female drivers 16 - 24 years old used self-serve stations more often than drivers of other ages.

Vehicle type and year

No female drivers 16 - 24 years old drove station wagons, while 11% of the females in the other age groups did. Drivers 16 - 24 are overrepresented with cars three to five years old and underrepresented with cars more than nine years old.

Who checks tire pressures?

Female drivers 16 - 24 years old who reported having their tires checked, check them personally more often than female drivers in the older age groups.

When was vehicle last serviced?

Females 16 - 24 years old reported servicing their cars less in the last three months than drivers in the other age groups. Considering the last nine months, there was no difference with age.

Perhaps the best way of describing the data is to compare the characteristics of those drivers and vehicles that had at least one tire more severely underinflated with those that had tires less severely underinflated or not underinflated. The cut-off differential pressure in this comparison was set at -6.0 psi. Moreover, as above, the difference between proportions in any one category was considered important if it differed by about 10% or more. The following characteristics emerged.

* Drivers of vehicles with more severe minimum differential pressures checked their tires less frequently in the previous six months than the other drivers.

* Of those who had their pressures checked at least once in the previous six months, about 54% of the drivers with the more severe underinflations checked their tires personally compared with 62% of the drivers with less severe underinflations. Thirty-two percent of the former group used the service station pump/gauge compared with 24% of the latter group.

* Of those with more severely underinflated tires, 48% are male, compared with 57% male drivers in the group with less severely underinflated tires.

* The incidence of more severe underinflations is about the same for all years of cars, but tends to be more common among vehicles with larger non-radial tires.

A significant, though surprising, result was the difference in mean ΔP that was found between front and rear tires. Rear tires, regardless of tread type, had a mean ΔP almost 2.0 psi less than that on front tires. Closer examination of the data suggests a reason for this result. Most manufacturers recommend higher pressures for the rear than for the front tires of their vehicles. For our survey, the mean recommended pressure for the front tires was 25.8 psi and for the rear tires 27.7 psi, almost 2.0 psi higher. Yet, it appears that most of us don't realize there should be different pressures for front and rear tires. The difference between the mean front and mean rear pressures estimated by our respondents was only about 0.4 psi. The incongruity, and perhaps the tragedy, in all of this is that even though over 75% of our respondents thought that tire pressures should be higher than the pressures recommended by the manufacturers, almost 70% of the tires on the road are underinflated.

In summary, the statistics from this survey paint a very gloomy picture. Over 60 percent of the cars on the road have at least one tire that is, what the industry terms, 'seriously' underinflated. This description can be misleading, however, since the industry doesn't publish information that relates the probability of tire failure to factors such as tire type, inflation pressure and vehicle load.

If, as we are led to believe, we are seriously at risk when driving with tire pressures as low as 4.0 psi *under* the recommended pressure, the majority of Canadian drivers are riding on at least one potential disaster and they don't seem to realize it.

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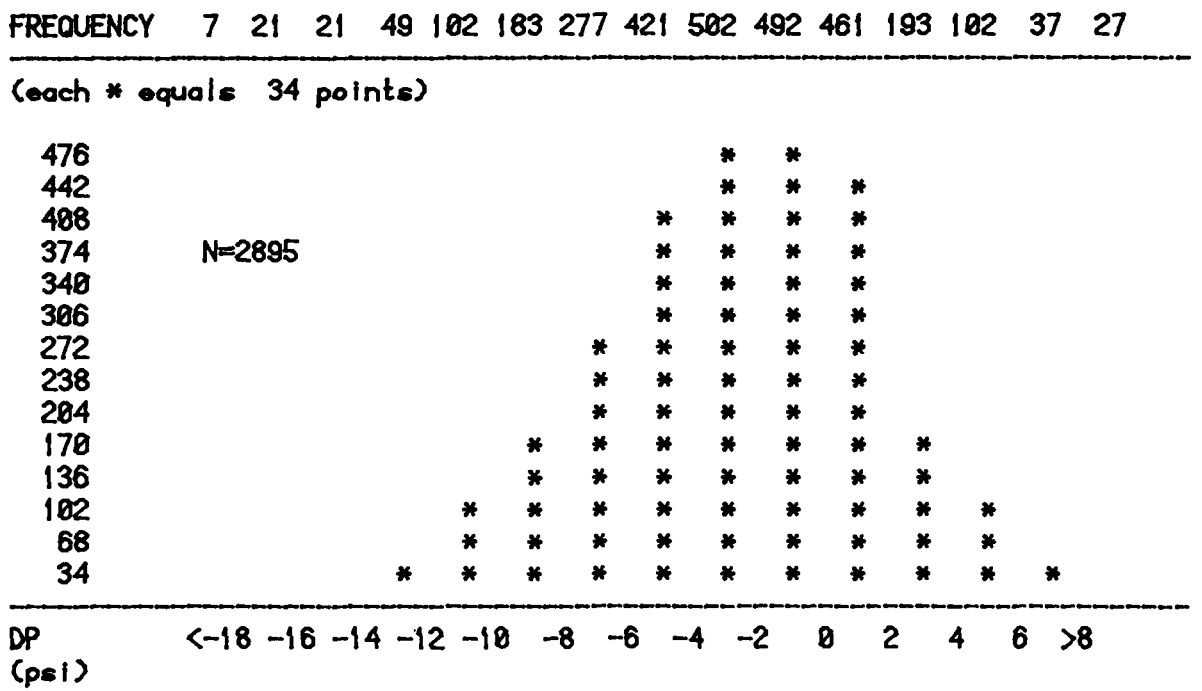
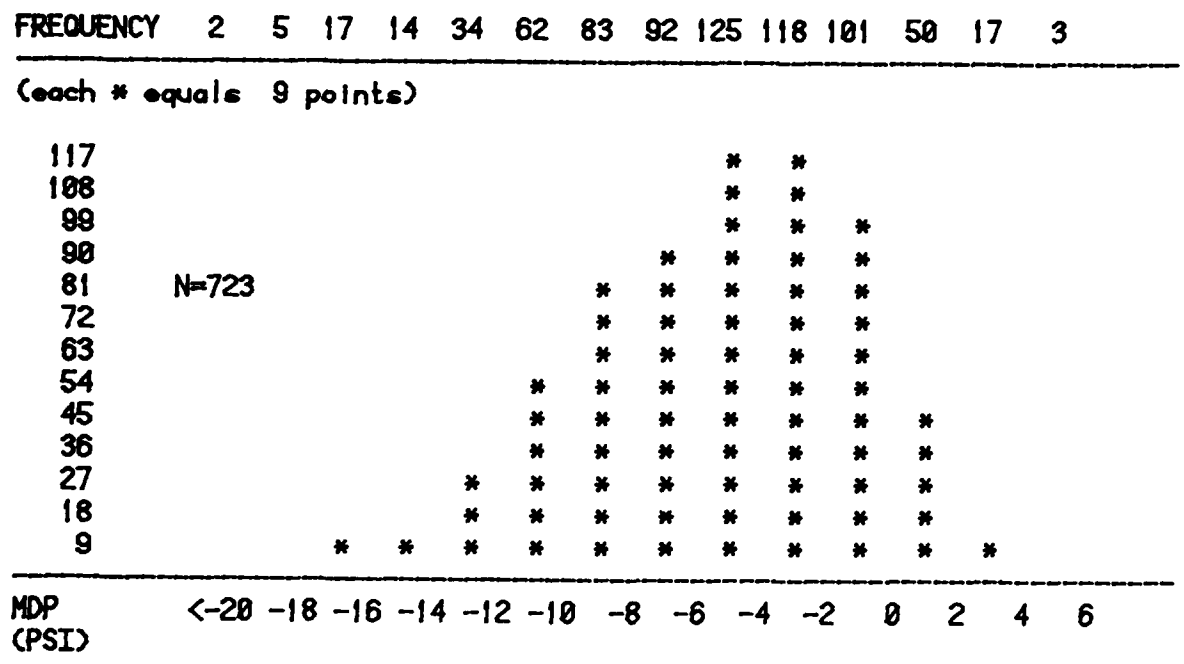
Figure 1: Histogram of differential pressures (DP)[1]
all tires.



[1] DP is defined on page 6 of the text.

Figure 2: Histogram of the minimum differential pressure (MDP)[1] per vehicle.



[1]MDP is defined on page 7 of the text.

TABLE 1: Distribution of households by city within a given population density stratum and region.

Region	Population Density (x1000) >500	100 - 499.999	30 - 99.999
Atlantic	---	Halifax (16)	Fredericton (12)
Quebec	Montreal (156) Quebec (26)	Chicoutimi/ Jonquiere (5)	Trois-Rivieres (30)
Ontario	Toronto (144) Ottawa (30)	St. Catharines/ Niagara (42) Windsor (36) Sudbury (22)	Kingston (36)
Prairies	Winnipeg (30) Edmonton (30)	Calgary (30) Regina (12)	Brandon (10)
British Columbia	Vancouver (61)	Victoria (12)	Kamloops (10)

TABLE 2: Number of respondents in the survey by Sex and Age range for each region.

Sex	Age Range	REGION Mar.	Que.	Ont.	Pra.	B.C.	Total
	16-24	2	21	8	8	3	42
	25-34	3	34	27	10	8	82
	35-44	1	33	27	7	12	80
Female	45-54	1	30	22	8	7	68
	55-64	0	32	12	3	8	55
	>= 65	0	14	6	2	1	23
	No Answer	0	1	0	0	0	1
Total Female		7	165	102	38	39	351
	16-24	5	5	23	13	10	56
	25-34	6	11	35	13	12	77
	35-44	2	15	50	13	7	87
Male	45-54	3	12	44	12	7	78
	55-64	3	4	29	11	4	51
	>= 65	1	1	28	11	4	45
	No Answer	0	0	0	0	0	0
Total Male		20	48	209	73	44	394
Total Respondents		27	213	311	111	83	745

TABLE 3: Number of tires surveyed by major manufacturer* and type.

Manufacturer	TIRE TYPE Non Radial	Radial	Can't Identify	Total Make	% Of Total Tires
Atlas #	60	24	0	84	2.8
Bridgeston	na**	na	na	27	0.9
Canadian Tire #	215	38	5	258	8.7
Continental	na	na	na	42	1.4
Cooper	na	na	na	10	0.3
Dayton #	8	2	0	10	0.3
Dunlop	na	na	na	76	2.6
Firestone #	171	201	11	383	12.9
General #	59	56	3	118	4.0
BF Goodrich #	85	136	3	224	7.5
Goodyear #	252	228	7	487	16.3
Gulf	na	na	na	61	2.0
Kelly/Springfield	na	na	na	32	1.1
Michelin	na	na	na	286	9.6
Pirelli	na	na	na	30	1.0
Sears	na	na	na	146	4.9
Shell	na	na	na	35	1.2
Uniroyal #	161	174	2	337	11.3
Woolco	na	na	na	21	0.7
Other ***	-	-	-	313	10.5
Total (na)	490	553	36	-	--
Total Tires	1501	1412	67	2980	100
% of Total	50.4	47.4	2.2	-	-

* The manufacturers originally specified for machine coding are identified with a #

** na = type was not computer coded against manufacturer.

*** Total other (313) includes those tires whose make could not be identified.

TABLE 4: Number of Tires surveyed by tread type and tread condition.

	TREAD TYPE				
Tread Condition	Winter	Summer	Other	Total Condition	% Of Total Tires
No Tread (Bald)	45	88	0	133	4
Some Tread	1000	1768	31	2799	94
No Answer	10	13	25	48	2
Total Type	1055	1869	56	2980	

TABLE 5: Estimates of the percentage of tires in the sample population having differential pressures (ΔP)[1] less than or equal to zero. The data in parentheses ( ) are 95 percent confidence intervals on the estimates.

ΔP (psi)	% of Tire below Pressure (All Tires)	% of Tires below Pressure (Radials)	% of Tires below Pressure (Non-Radials)
0.0	71.7	69.5	73.7
	(70.1 - 73.3)	(67.1 - 71.9)	(71.5 - 75.9)
-2.0	54.7	52.4	56.8
	(52.9 - 56.6)	(49.8 - 55.0)	(54.3 - 59.3)
-4.0	37.3	34.1	40.3
	(35.5 - 39.1)	(31.6 - 36.6)	(37.8 - 42.8)
-6.0	22.8	20.7	24.7
	(21.3 - 24.3)	(18.6 - 22.8)	(22.5 - 26.9)
-8.0	13.2	10.8	15.5
	(12.0 - 14.4)	(9.7 - 12.4)	(13.7 - 17.3)
-10.0	6.9	4.8	8.9
	(6.0 - 7.8)	(3.7 - 5.9)	(6.0 - 7.8)

[1] ΔP is defined on page 6 of the text.

TABLE 6: Estimates of the percentage of vehicles in the sample population that have at least one tire with a differential pressure (ΔP)[1] less than or equal to zero. The data in parentheses ( ) are 95 percent confidence intervals on the estimates.

ΔP (psi)	% of vehicle with one tire below pressure (All Tires)	% of vehicle with one tire below pressure (Radials)	% of vehicles with one tire below pressure (Non-Radials)
0.0	90.3	87.6	90.3
	(88.1 - 92.5)	(84.0 - 91.3	(87.2 - 93.4)
-2.0	76.3	75.9	74.8
	(73.2 - 79.4)	(71.2 - 80.6)	(70.2 - 79.4)
-4.0	60.0	57.0	60.0
	(56.4 - 63.6)	(51.6 - 62.4)	(54.9 - 65.3)
-6.0	42.7	38.7	43.4
	(39.1 - 46.3)	(33.4 - 44.0)	(38.1 - 48.7)
-8.0	30.0	25.4	31.7
	(26.7 - 33.3)	(20.7 - 30.2)	(26.8 - 36.6)
-10.0	18.5	14.6	20.8
	(15.7 - 21.3)	(10.8 - 18.5)	(16.5 - 25.1)

[1] ΔP is defined on page 6 of text.

TABLE 7: Manufacturer of last tire to be replaced for reasons other than normal wear and tear by tire type and inside diameter*

Manufacturer	Radial <15 inch	Radial =>15 inch	Non-Radial <15 inch	Non-Radial =>15 inch	No Specifications	Total Make	% of Total
Atlas	-	-	2	2	-	4	2.0
Bridgestone	-	-	1	-	-	1	0.5
Canadian Tire	4	2	7	3	1	17	8.3
Continental	1	-	-	-	-	1	0.5
Cooper	-	1	-	-	-	1	0.5
Dunlop	3	-	1	-	-	4	2.0
Esso	-	-	-	-	1	1	0.5
Firestone	7	26	6	7	3	49	24.0
General	2	1	-	-	-	3	1.5
BF Goodrich	4	8	1	1	-	14	6.9
Goodyear	12	15	9	3	-	39	19.1
Gulf	1	-	-	1	1	3	1.5
Kelly/Springfield	1	-	-	1	-	2	1.0
Michelin	4	8	-	-	1	13	6.4
Pirelli	1	-	-	-	-	1	0.5
Sears	2	2	2	1	1	8	3.9
Shell	-	-	1	-	-	1	0.5
Uniroyal	5	12	3	1	-	21	10.3
Volkswagon	-	-	-	-	1	1	0.5
Woolco	1	-	1	-	-	2	1.0
D/K N/A	6	3	7	1	1	18	8.8
Column Total	54	78	41	21	10	204	
% Of Total	26.5	38.2	20.0	10.3	4.9	100	

Total Type % Rad = 132 (64.7) Non-Rad = 62 (30.4)

Total Size % <15 Inch= 95 (46.6) => 15 Inch= 99 (48.5)

* The above are absolute numbers and do not necessarily reflect either the number of tires of a given type that have been in service or the number or type of miles that each has been subjected to.

TABLE 8: Mean (*MIN* ΔP) and Variance (S^2) of Minimum differential pressures [1] by the age grouping and sex of the principal driver.

Sex	Age Group	N	*MIN* ΔP	S^2
Male	16-24	56	-6.7	34.7
	25-34	77	-5.3	28.7
	35-44	87	-5.6	23.6
	45-54	78	-4.6	19.2
	55-64	51	-6.6	25.4
	>= 65	45	-5.0	36.3
Female	16-24	42	-8.1	37.4
	25-34	82	-5.5	26.9
	35-44	80	-7.3	45.8
	45-54	68	-6.3	46.1
	55-64	55	-7.7	42.9
	>= 65	23	-7.8	48.2

[1] Minimum differential pressure is defined on page 7 of the text.

TABLE 9: Mean ($MIN\ \Delta P$) and Variance (S^2) of minimum differential tire pressures[1] by Region.

Region	N	$MIN\ \Delta P$	S^2
Maritimes	26	-5.7	25.7
Quebec	207	-5.8	23.0
Ontario	300	-5.9	22.6
Prairies	107	-5.5	25.4
B.C.	83	-3.9	19.1

[1] Minimum differential tire pressure is defined on page 7 of the text.

TABLE 10: Mean (ΔP) and Variance (S^2) of differential tire pressures[1] by Radial/Non-Radial and size.

	Size	N	ΔP	S^2
Radial	<14	243	-1.7	16.9
	=14	475	-2.4	21.4
	>14	682	-2.7	18.4
Non-Radial	<14	265	-2.1	25.4
	=14	729	-3.7	24.3
	>14	501	-2.3	30.5

[1] Differential tire pressure is detined on page 6 of the text.

TABLE 11: Frequency of use of self-serve stations by age groupings and sex.

Frequency of Use	MALE				FEMALE			
	16-24		>24		16-24		>24	
	N	%CT	N	%CT	N	%CT	N	%CT
Never	12	21	95	28	11	26	130	42
1/4 Time	4	7	29	9	3	7	14	5
1/2 Time	6	11	39	12	8	19	29	9
3/4 Time	3	5	25	7	7	17	26	8
Always	31	55	150	44	13	31	110	36
D/K N/A	0	0	0	0	0	0	0	0
Column Total (CT)	56		338		42		309	